Aerosonde Technical Development

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LONG-TERM GOALS

The Aerosonde development program has been in effect since the early 1990's with the first field trial flown at the end of 1995 as part of the Maritime Continental Thunderstorm Experiment of northern Australia (McGeer 1996b). Since that time, the Aerosonde has been deployed in diverse jurisdictions and climates in collaboration with the weather services of Australia, Canada, Taiwan and the U.S. Principal results are as follows:

- more than 1000 flight hours since 1995
- deployment with relative ease (except still requiring significant ground support personnel)
- seven flights longer than 24 hrs with the longest flight of 30.5hr.
- flights in severe tropical thunderstorms (Western Australia, South China Sea)
- flights in midlatitude icing (Vancouver Island)
- flights in the arctic environment (Barrow)
- fully automatic flight from takeoff to landing
- control of multiple aircraft from a single ground station
- inflight transfer between ground stations and enroute control-by-telephone from weather forecasting centers
- first unmanned Atlantic crossing; 3270 km from Newfoundland to Scotland on 20-21 August, 1998 in 26 hr 45 min using 4 kg of fuel

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In 1999, ONR funded further engineering development of the Aerosonde at the University of Washington. This funding was further supplemented by a contract from Aerosonde Robotic Aircraft of Australia (replacing SES). The major goals are to develop the necessary tools for a technology base supporting Aerosonde class aircraft design while improving the current vehicle. Secondary goals for the UW are to integrate the Aerosonde development effort into the educational mission of the Department of Aeronautics and Astronautics.

OBJECTIVES

1. Investigation of the aerodynamic characteristics of the current Aerosonde configuration with the goal of improving the drag characteristics,
   - 1.1. Modifications to the existing airframe will be tested in the Kirsten wind tunnel to measure drag reduction of candidate configurations.
   - 1.2. CFD panel methods and Navier-Stokes codes will be used to simulate the behavior of the current design and modifications to the current design.
   - 1.3. Wind tunnel tests of alternative UAV designs will be used to validate the CFD panel methods and Navier-Stokes codes.
   - 1.4. Develop rapid wind tunnel model construction techniques to lower the cost and increase the productivity of wing tunnel testing new configurations
2. Development of a simulation environment for rapid evaluation of autopilot designs,
   - 2.1. Develop a real-time Aerosonde simulation code using SIMULINK.
   - 2.2. Develop the Aerosonde flight control system using SIMULINK, REAL-TIME WORKSHOP and STATEFLOW to provide a better workable environment for the development/revision of current flight control systems.
3. Analysis of the structural / aeroelastic characteristics of the current airframe.
   - 3.1. Develop computational, experimental and manufacturing tools for the rapid aeroelastic analysis, design, and construction of low-cost UAV airframes.
   - 3.2. Build technology to support aeroelastic simulation and modification of Generation-I Aerosondes as well as future generation Aerosondes.
4. Development of trajectory optimization algorithms to facilitate operations.
   - 4.1. Develop a real-time trajectory and flight path planning algorithm for the Aerosonde that determines the optimal path under various types of constraints.
5. Involve graduate students in graduate research
   - 5.1. Grad students will be involved in application / development of simulation tools.
   - 5.2. Grad students will participate in design of modifications to Generation 1 Aerosondes and future designs
   - 5.3. Grad students will be involved in development of real time trajectory planning and management algorithms.
6. Incorporate design/analysis of Aerosonde class vehicles in the undergraduate curriculum.
   - 6.1. Undergraduates will design UAVs as part of the capstone design course.
   - 6.2. Students will participate in the design and building of UAV hardware
   - 6.3. Independent studies projects will explore new designs.

APPROACH

- 1.1. Modifications to the existing airframe will be tested in the Kirsten wind tunnel. (Eberhardt)
- 1.2. Three levels of aerodynamic prediction tools will be applied to Aerosonde configurations: vortex lattice, panel and Navier-Stokes. (Eberhardt, Livne)

1.3. Wind tunnel data will be used to validate simulation codes. (Eberhardt, Livne)
1.4. Students will use CAD modeling and rapid prototyping to allow multiple designs to be tested for optimizing next generation Aerosonde-class UAV's. (Livne)
2.1. A tracking algorithm will be developed for the yaw rate command that reduces lateral track error to a flight-path segment. (Ly)
2.2. The Raven autopilot will be designed and implemented using Simulink, Real-Time Workshop and StateFlow and its performance tested using hardware-in-the-loop simulation. (Ly)
2.3. The development tools (Simulink, Real-Time Workshop and AZTEC compiler) will be used to develop a library of C-mex S-functions for the device drivers and test them on the Tattletale 8. (Ly)
3.1. Collaboration with industry (ATS) in the development of low manufacturing costs for wind tunnel models. (Livne)
4.1. Various numerical schemes will be reviewed for solving the trajectory planning and management optimization problem (Vagners)
5.1. Train graduate research assistants in the use of simulation and experimental tools and have them interact with the industry developers. (All)
5.2. Include graduate students as teaching assistants and team leaders for the design of new Aerosonde-class UAV's. (All)
6.1. The two-quarter airplane design sequence (AA410/411) will focus on the design, testing and building of UAV's of the Aerosonde-class. (Livne)
6.2. Students will participate in the building of hardware through the airplane design courses, independent studies and extra-curricular activities. (All)
6.3. Independent projects for credit will be offered so students can focus on a particular technology in the program that interests them. (All)

WORK COMPLETED

1.1. Panel grids for CMARC and 3D grids using ICEM-CFD have been created and preliminary results obtained.
1.2. Fuselage drag was carefully measured in the wind tunnel to determine its contribution to the total drag calculations performed.
2.1. A new robust lateral tracking control-law for the Aerosonde has been developed.
2.2. Raven autopilots have been designed and implemented. The real-time control-law obtained was successfully implemented on the Tattletale 8 and tested in hardware-in-the-loop simulation.
2.3. Device drivers specific to analog inputs, discrete I/O, serial input from GPS receiver, serial output to servo controllers, flash memory storage, LCD display have been written and tested.
3.1. The finite element code ANSYS, with its CAD geometry interfaces, was used for the first time to reduce stress concentrations on a light-weight Kevlar/foam wing of a mini-UAV.
3.2. A second prototype vehicle was built using inexpensive materials and construction. Alternative construction techniques for Aereosonde class low-cost UAVs were studies and cost / weight / quality of surfaces evaluated.
4.1. The real time trajectory planning and management problem for Aerosonde class UAVs in the presence of realistic wind models and icing conditions has been formulated. Alternative numerical algorithms were evaluated, and two algorithmic approaches based on the D* algorithm and evolutionary programming were selected for testing and evaluation.
5.1. Three graduate students are currently working on the Aerosonde program.
5.2. Graduate students are leading design and building efforts with undergraduates.

6.1. UAV’s of the Aerosonde-class have been integrated into the curriculum of the capstone design courses (AA410/411).
6.2. 10 undergraduate students are working on the program as an extra-curricular activity. Students have designed and built a joined-wing design.

RESULTS

Most tasks are still in progress, which has been described in the previous section. This section will focus on only those results which can result in significant impact in this or related programs.

1.1. Drag on the current Aerosonde fuselage is unacceptably high due to, mainly, base-drag. Longer fuselages were tested and found to have less drag.
1.2. Limitations of panel codes are understood. As a result, 3-D Navier-Stokes grids have been produced in preparation for N-S simulations.
2.1. A robust lateral track control-law has been developed for the low-wind conditions and tested in simulation to track a flight-path segment. In high-wind conditions, the track algorithm was modified to take into account the wind direction.
2.2. A library of C-mex S-functions of device drivers has been written to allow rapid interfaces with the Tattletale 8 for the following external devices: LCD display, serial inputs for GPS receiver, serial outputs for servo controllers, data storage to RAM and flash memory, discrete inputs and outputs, and analog inputs.
3.1. Coupon tests and overall airframe structural tests added important information that can be now used for the design of low-cost all-composite UAVs using Graphite/Epoxy and Kevlar/Epoxy material systems and various structural layout concepts and manufacturing techniques.
3.2. ANSYS numerical predictions helped solve a stress concentration / local failure problem on a new light-weight wing.
4.1. Simulation of D* and evolutionary programming optimal path planning algorithms integrated with the Aerosonde trajectory models and approximations to the wind field have been implemented and evaluated.
5.1. Three graduate students are currently working on the Aerosonde program
5.2. Graduate students are leading design and building efforts with undergraduates
6.1. UAV’s have been integrated into the capstone design courses (AA410/411). Students have designed, built and tested a new UAV called “Aerodawg”.
6.2. 10 undergraduate students are working on the program as an extra-curricular activity. Students have designed and built a joined-wing design.

IMPACT/APPLICATIONS

1. Aerodynamic improvements will help increase range and endurance of the existing Aerosonde, allowing it to collect meteorological data over a larger area.
2. Low cost / fast construction of prototypes can lead to quicker and cheaper engineering solutions.
3. A robust lateral track control-law enables stable tracking of flight path segments.
4. A library of C-mex S-functions of device drivers provide user-friendly interfaces with the Tattletale 8.

TRANSITIONS

1. Placement of pressure probes has been changed as a result of wind tunnel experiments.

RELATED PROJECTS

“Aerosonde Performance Improvement and Economical Wide-Scale Weather Reconnaissance over the Oceans,” PI: D. S. Eberhardt, Co-PI: E. Livne, U-L Ly, and J. Vagners. ONR DURIP (Equipment Grant). Grant N00014-98-1-0372. The funding provides the equipment required to carry out the research. Ten Aerosondes have been purchased and used for collecting data pertinent to this research project. In addition, the Aerosondes have been used for trial weather collection programs.

PUBLICATIONS

1. "Rapid Prototyping Platform for Flight Control System Design," MSAA thesis, Department of Aeronautics and Astronautics, University of Washington, Seattle, Washington, June 2000.
2. "Lateral Track Control Law for Aerosonde UAV", AIAA Student Paper, to be presented at the 39th AIAA Aerospace Sciences Meeting, at Reno, Nevada, Jan 8-11, 2001.
3. "Integrated Synthesis of Aircraft for Combined Mission / Stability and Control Requirements", Douglas Galloway, MSAA thesis, Department of Aeronautics and Astronautics, University of Washington, Seattle, Washington, July 2000.